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**Singh**

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(54) **EXPANDED SCOPE INCREMENTER**

(56) **References Cited**

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This patent is subject to a terminal disclaimer.

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**Related U.S. Application Data**

(62) Division of application No. 12/852,660, filed on Aug. 9, 2010, now Pat. No. 8,554,821.

(51) **Int. Cl.**  
**G06F 7/50** (2006.01)  
**G06F 7/505** (2006.01)

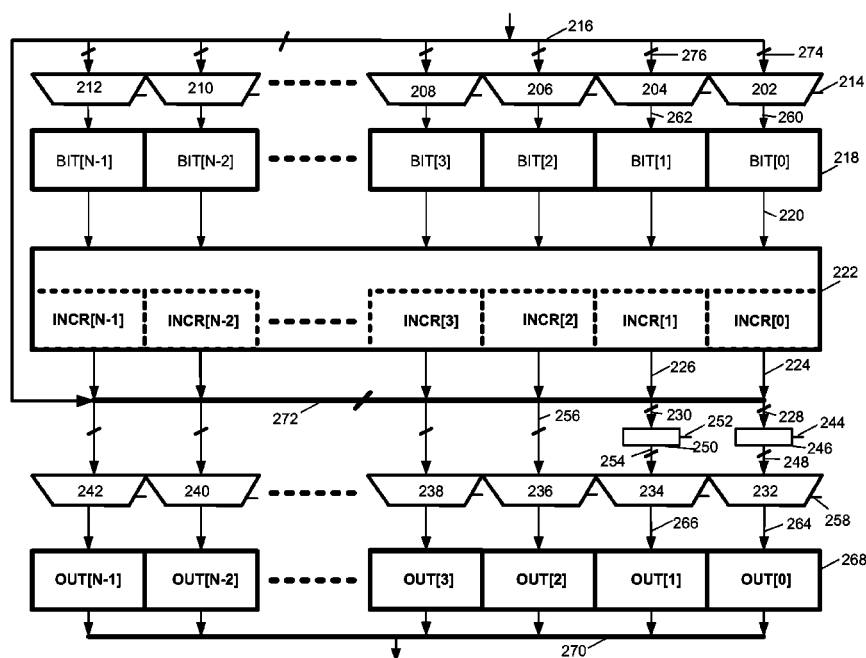
(52) **U.S. Cl.**  
CPC ..... **G06F 7/5055** (2013.01)

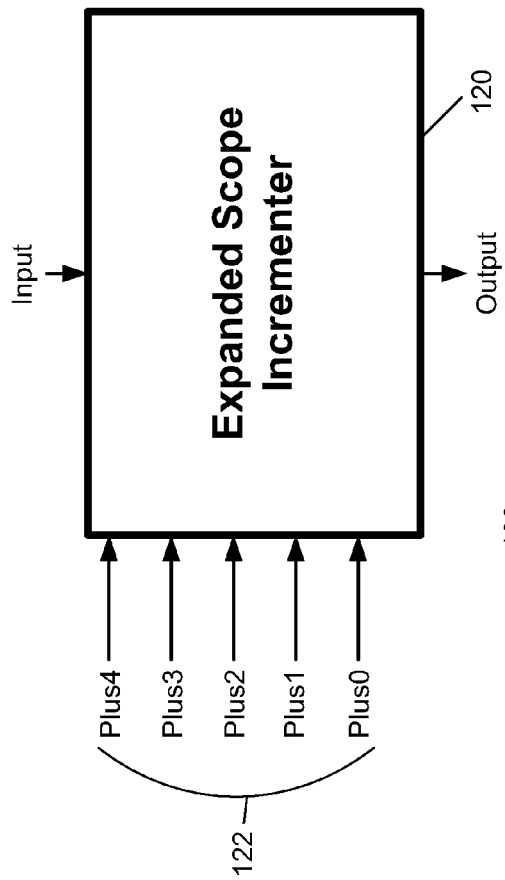
(58) **Field of Classification Search**  
USPC ..... 708/672  
See application file for complete search history.

(57) **ABSTRACT**

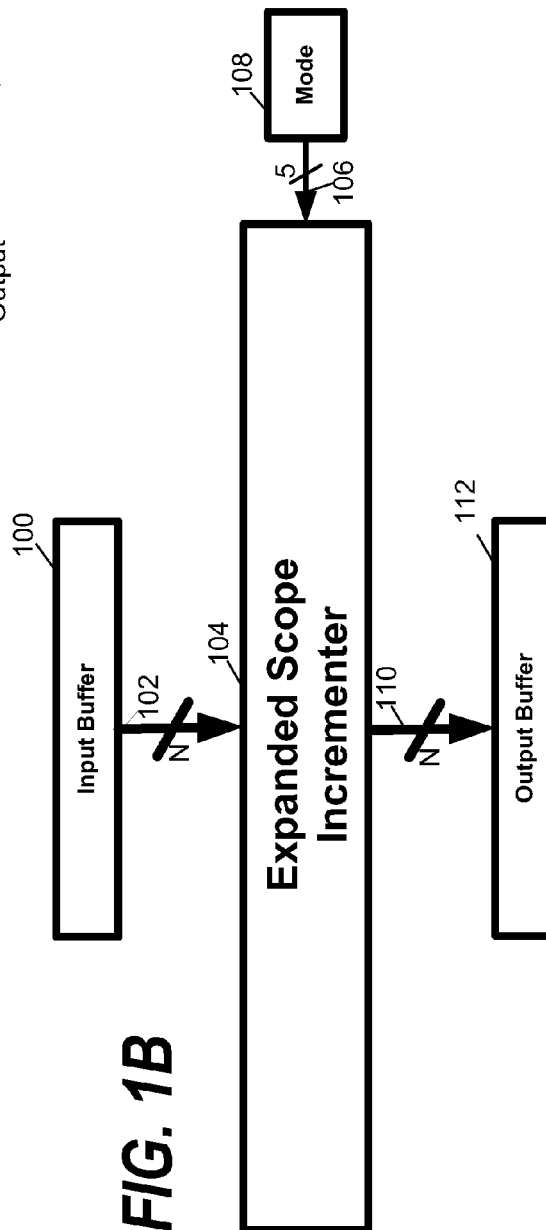
An incrementor circuit and method for incrementing is provided that computes an output data word by increasing an input data word magnitude by one of several integer values. The incrementor circuit includes a mode increment signal circuit providing a designation of one of the integer values for increasing the input data word magnitude. A single constant incrementor is connected to the mode increment signal circuit and the input data word and provides an intermediate sum by selectively adding a constant to the input data word. A multiplex circuit logically combines selected input data word bit position values with the mode increment signal circuit designation forming logical bit position values and directs selected input data word bit position values, selected logical bit position values, and selected bit position values of the intermediate sum to form the output data word.

**7 Claims, 5 Drawing Sheets**





**FIG. 1A**



**FIG. 1B**

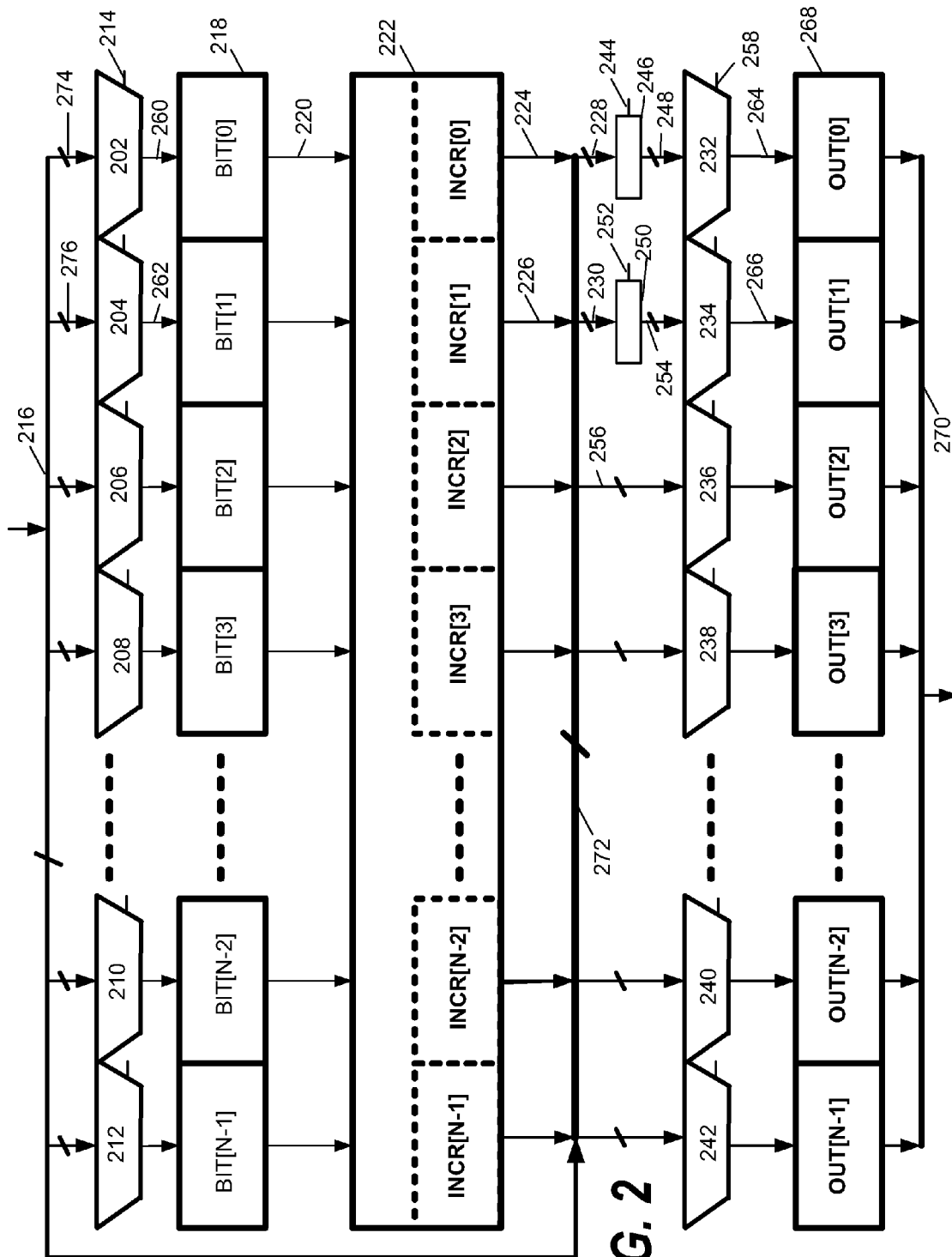
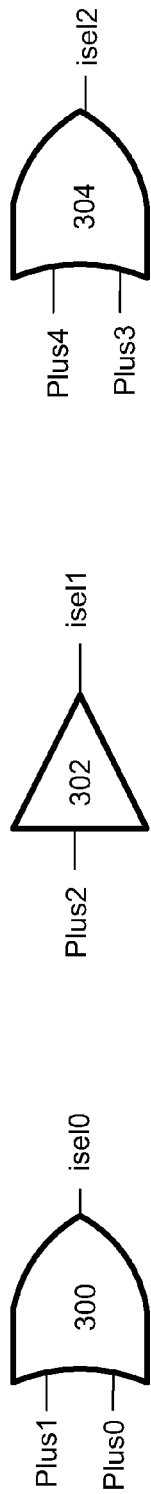
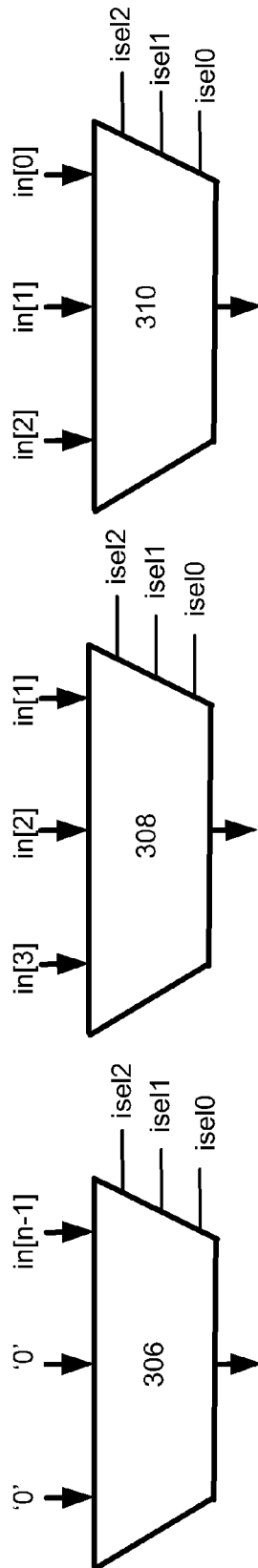
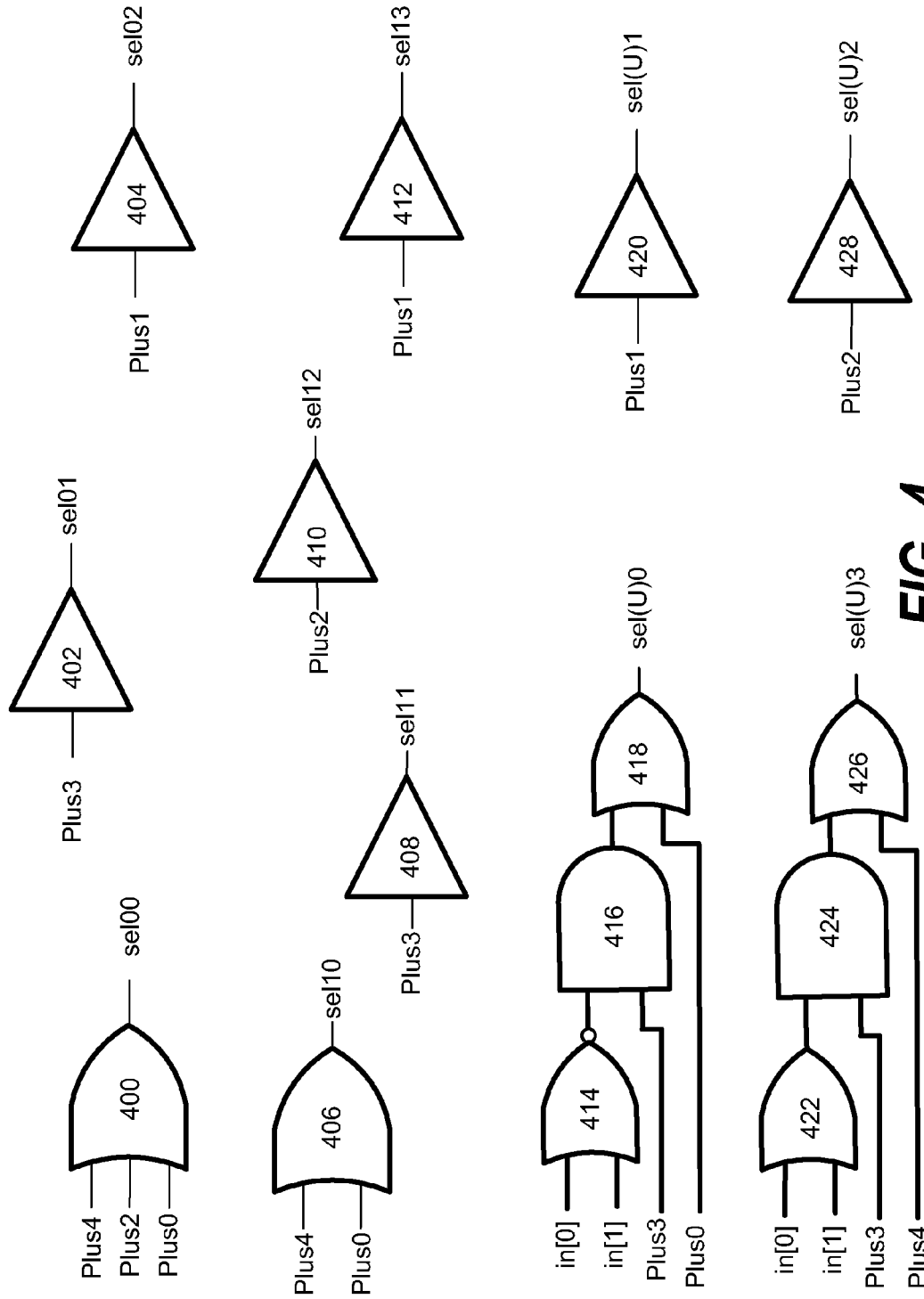


FIG. 2

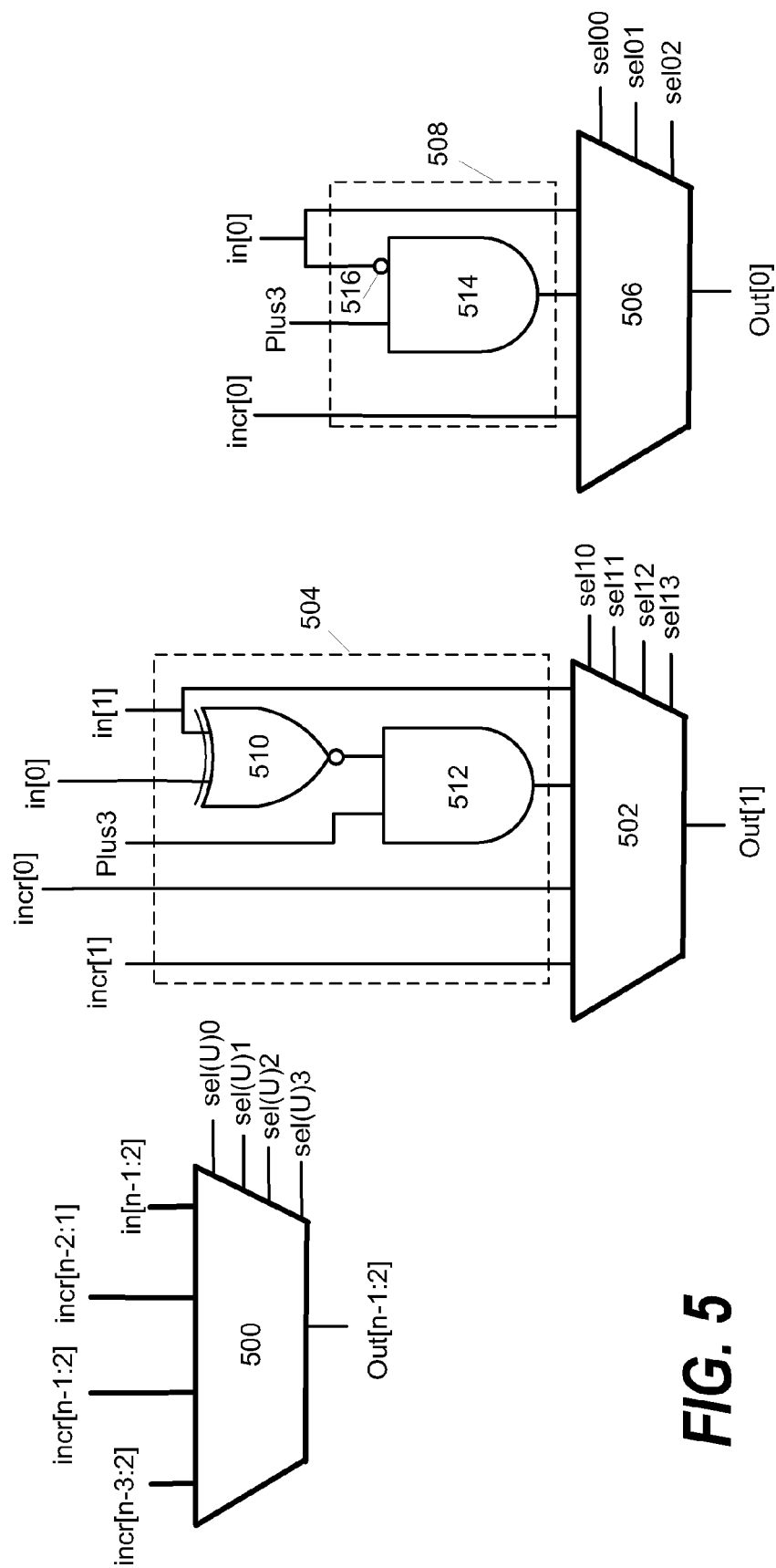


**FIG. 3**





**FIG. 4**



## EXPANDED SCOPE INCREMENTER

## CROSS REFERENCE TO RELATED APPLICATIONS

This application is a divisional of, and claims benefit of the filing date of, copending U.S. patent application Ser. No. 12/852,660 entitled "EXPANDED SCOPE INCREMENTOR," filed Aug. 9, 2010.

## BACKGROUND OF THE INVENTION

## 1. Technical Field

The present invention relates to digital computers. In particular, the present invention relates to addition circuits in digital computers.

## 2. Description of the Related Art

Digital computers perform arithmetic computations in executing software programs. The function of computing a sum is accomplished by adder which can be, given a long data word length such as 64 bits or 128 bits wide, a complex circuit. Adders receive two inputs and produce an output that is the sum of the two inputs. However, for additions where one of the inputs has a value of binary 1, an incrementor is used. The incrementor is commonly employed for computing addresses where an address is incremented by one to obtain a next in sequence address. However, if a different type sum is required, the more complex adder is used.

## SUMMARY

In accordance with the present invention, an incrementor circuit for computing an output data word by increasing an input data word magnitude by one of several integer values is provided. The incrementor circuit includes a mode increment signal circuit providing a designation of one of integer values for increasing the input data word magnitude. A single constant incrementor is connected to the mode increment signal circuit and the input data word and provides an intermediate sum by selectively adding a constant to the input data word. A multiplex circuit logically combines selected input data word bit position values with the mode increment signal circuit designation forming logical bit position values and directs selected input data word bit position values, selected logical bit position values, and selected bit position values of the intermediate sum to form the output data word.

## BRIEF DESCRIPTION OF THE DRAWINGS

The present invention may be better understood, and its numerous objects, features, and advantages made apparent to those skilled in the art by referencing the accompanying drawings.

FIG. 1A is a block diagram of the extended scope incrementor;

FIG. 1B is a block diagram illustrating a second embodiment of the extended scope incrementor;

FIG. 2 is block diagram illustrating an embodiment of the extended scope incrementor including a dual level multiplexer configuration with a single incrementor;

FIG. 3 is a schematic diagram illustrating a first level multiplexer configuration;

FIG. 4 is a schematic diagram of the select signal generation for a second level multiplexer configuration; and

FIG. 5 is a schematic diagram of the second level multiplexer configuration.

## DETAILED DESCRIPTION

The following is intended to provide a detailed description of an example of the invention and should not be taken to be limiting of the invention itself. Rather, any number of variations may fall within the scope of the invention, which is defined in the claims following the description.

The present invention is an incrementor circuit and a method for incrementing that includes computing an output data word by increasing an input data word magnitude by one of several integer values. The incrementor circuit includes a mode increment signal circuit providing a designation of one of several integer values for increasing the input data word magnitude. A single constant incrementor is connected to the mode increment signal circuit and the input data word and provides an intermediate sum by selectively incrementing a constant to the input data word. The incrementing may be done on upper n-bits, n-1 bits or n-2 bits of the input data word depending upon the mode. A multiplex circuit logically combines selected input data word bit position values with the mode increment signal circuit designation forming logical bit position values and directs selected input data word bit position values, selected logical bit position values, and selected bit position values of the intermediate sum to form the output data word.

As will be appreciated by one skilled in the art, aspects of the present invention may be embodied as a circuit, system, or a method. Accordingly, aspects of the present invention may take the form of an entirely hardware embodiment or include software (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects that may all generally be referred to herein as a "circuit," "module" or "system."

As previously discussed, historically incrementors are circuits that add a single integer constant, '+1', to an input value. Incrementors are commonly used to increase an address value in order to access the next sequentially located address word. One example is a program counter that is used to access the next sequentially located instruction. However, in some computer systems, it is advantageous to add one of several different constant integers to a value. For example an effective address may need to be incremented by different integer values in order to access the same byte (+0), a next byte (+1), a next double word (+2), an address that is three bytes away (+3), or a next word (+4). The following expanded scope incrementor invention provides an incrementor that may add numeric values of +0, +1, +2, +3, or +4 in a single operation. The expanded scope incrementor does not have the complexity of a full scale adder and, therefore, uses a much smaller area than a full scale adder. This results in the expanded scope incrementor using less power and fewer routing resources while executing faster than a full-scale adder.

FIG. 1A is a block diagram illustrating an extended scope incrementor **120** connected to receive an input and to provide an output. Additionally the expanded scope incrementor includes five selection signals **122** that would select one of five different integer values for the input magnitude to be incremented by. These values are +0, +1, +2, +3, and +4. This can also be expanded to add +1, +2, . . . , +5, +6, etc . . . and the number of selects will accordingly increase.

FIG. 1B is a block diagram illustrating an expanded scope incrementor **104** connected to an input buffer **100** that provides binary input data word over a parallel input bus **102** into the expanded scope incrementor **104**. Additionally, the expanded scope incrementor **104** receives a mode select signal from a mode circuit **108**. In a preferred embodiment, the mode select signal is one of five signals input to the expanded

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scope incrementor **104** on line **106**. After incrementing the value from the input buffer **100**, the expanded scope incrementor **104** would provide on lines **110** the output value to an output buffer **112**. This output value is the input value increased by a magnitude specified by the mode circuit **108**. In other words, the input value would be increased by one of the increment values of +0, +1, +2, +3, and +4.

FIG. 2 is a schematic diagram of the internal circuitry in the expanded scope incrementor **104** of FIG. 1B. In FIG. 2, a row of multiplex circuits **202**, **204**, **206**, **208**, **210** and **212** represent multiplexers that each receive bit position values of an input data word via bus **216**. In other words, each multiplexer, such as multiplexer **202**, would receive several parallel bit position values from the input data word. In one embodiment, multiplexer **202** is a three input multiplexer selecting one of three input lines to provide as an output based upon a select signal. In this embodiment, multiplexer **202** receives the three least significant bit position values of the input data word. As a definition of bit positions, an 8-bit word contains bit positions of 7 to 0 where bit position 0 is the least significant bit position of the word. In this embodiment with an input data word containing *n* bits, multiplexer **212** would receive input data word bit position *n*-1 (or bit position 7 for an 8 bit word) and two null or '0' inputs. Multiplexer **210** would receive bit position *n*-1 (or bit position 6 for an 8 bit word), bit position *n*-2 and a single null or '0' input. The remaining multiplexers **208**, **206** and **204** would receive three inputs according to this sequence of input positions. Additionally, multiplexers **202**, **294**, **206**, **208**, **210** and **212** receive a mode select signal illustrated on line **214** for multiplexer **202**. This mode select signal designates the incrementing value such as, for this illustrated embodiment, +0, +1, +2, +3 or +4.

In FIG. 2, a bit buffer **218** is illustrated as receiving bit positions BIT[N-1] through BIT[0]. In a slightly varied implementation, the incrementor can also be modified to produce a carry bit. This carry along with the upper 2 bits from the incrementor INCR[N-1], INCR[N-2] can be sent to a mux that can select one of them depending upon the mode, to generate an overflow bit indicating that the output of this circuitry has overflowed. Each bit position of the bit buffer **218** is provided to a corresponding bit position of a single integer constant incrementor **222**. In this embodiment, the incrementor **222** is simply a +1 incrementor. Incrementor **222** provides each bit position output, such as lines **224** and **226**, to a data bus **272** which includes the input data word bus **216**. In this embodiment two sets of parallel lines, **228** and **230**, from data bus **272** are provided to logic circuits **246** and **250** respectively which in turn, provide parallel inputs to multiplexers **232** and **234** on lines **248** and **254** respectively. Logic circuits **246** and **250** include lines **244** and **252** to receive mode select signals. The other multiplexers, **236**, **238**, **240** and **242** receive inputs directly from data bus **272**. Each of the multiplexers **232**, **234**, **236**, **238**, **240** and **242** also receive mode select signals as illustrated on line **258** for multiplexer **232**. The single bit positions outputs of multiplexers **232**, **234**, **236**, **238**, **240** and **242** are then provided over lines such as **264** and **266**, for multiplexers **232** and **234** respectively, to an output buffer **268**. The output buffer **268** provides the output data word on output data bus **270**.

In the illustrated embodiment, buffers **218** and **268** are provided but are optional. In another embodiment, these two buffers **218** and **268** are not required.

FIG. 3 illustrates three multiplexers **306**, **308** and **310** that correspond to top row of multiplexers **212**, **204** and **202** in FIG. 2 respectively. The three multiplexers **306**, **308** and **310** illustrate the 3 input lines and the 3 multiplex select signals. The multiplex select signals lse10, lse11 and lse12 result

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from the two OR gates **300** and **304** and driver **302** which receive the input mode select signals Plus0, Plus1, Plus2, Plus3, and Plus4.

FIG. 4 illustrates the schematic logic to convert the mode select signals Plus0, Plus1, Plus2, Plus3, and Plus4 to the multiplex select signals for the bottom row of multiplexers **232**, **234**, **236**, **238**, **240** and **242** of FIG. 2. In FIG. 4, OR gate **400** and drivers **402** and **404** provide the three multiplex select signals (signals sel100, sel101 and sel102) for the least significant bit position bottom row multiplexer **232** (FIG. 2). The other bottom row multiplexers **234**, **236**, **238**, **240** and **242** (FIG. 2) each receive four multiplex select signals. OR gate **406** and drivers **408**, **410** and **412** provide the multiplexer select signals sel10, sel11, sel12, sel13 and sel14 for multiplexer **234** (FIG. 2). The other multiplexers **236**, **238** and **240** also receive multiplex select signals as shown for multiplexer **242**. The most significant bit multiplexer **242** (FIG. 2) receives the four multiplexer select signals sel(U)0, sel(U)1, sel(U)2 and sel(U)3. For sel(U)0, both the least significant bit in[0] and the next to the least significant bit in[1] of the input data word are provided to NOR gate **414** and combined with Plus 3 and Plus0 in AND gate **416** and OR gate **418** as shown. In a similar manner, for sel(U)3, in[0] and in[1] are provided to OR gate **422** and combined with Plus3 and Plus4 in AND gate **424** and OR gate **426**. Plus2 provides sel(U)1 from driver **420** and Plus2 provides sel(U)2 from driver **428**.

In FIG. 5, the multiplexer select signals generated by the circuitry illustrated in FIG. 4 are provided to multiplexers **500**, **502** and **506**. Multiplexer **500** represents several multiplexers which receive four inputs to provide the Out[n-1:2] values of the output data word. In other words, the binary values of the output data word from the most significant bit position to the third least significant bit position Out[2] are each provided by multiplexers such as multiplexer **500** connected to receive the multiplexer select signals sel(U)0, sel(U)1, sel(U)2 and sel(U)3 with inputs provided as illustrated.

In FIG. 5, the multiplexer **502** provides the output data word bit position value Out[1]. The four input lines of the multiplexer **502** are selected by the multiplexer select lines sel10, sel11, sel12, and sel13 as discussed. However, the four input lines included logic circuitry **504** (corresponding to logic circuit **250** of FIG. 2) that combine the input data word values in[0] and in[1] in an Exclusive NOR gate **510** which is logically combined with Plus3 in an AND gate **512** to provide one of the inputs. The other inputs are incr[1] and incr[0], the two least significant bit position values from the incrementor **222** (FIG. 2) and the input data word bit position value in[1] as shown. These inputs incr[1], incr[0], in[0], and in[1] are provided by the data bus **272** from lines **230** shown in FIG. 2.

Likewise, logical circuitry **508** (corresponding to logic circuit **246** in FIG. 2) provides the three inputs (line **248** in FIG. 2) to the multiplexer **506**. Two inputs incr[0] and in[0] are provided directly to multiplexer **506** but the remaining input is provided by logically combining in[0] through an inverter **516** to an AND gate **514** that also receives as an input Plus3. The inputs incr[0] and in[0] are provided by the data bus **272** from lines **228** shown in FIG. 2.

This expanded scope incrementor uses the multiplexers to provide shifting functions and bit position direction functions while employing the single constant incrementor and logical circuitry to provide the frequently used function of adding these integer values without the need of a full scale adder. This concept can also be extended to add +1, +2, +3, +4, +5, +6, +7, +8, etc with some additional hardware. As previously discussed, the incrementor can also be modified to produce a carry bit. This carry along with the upper 2 bits from the incrementor INCR[N-1], INCR[N-2] can be sent to a mux

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that can select one of them depending upon the mode, to generate an overflow bit indicating that the output of this circuitry has overflowed. Further, the mode select signals are expected to be one-hot, i.e. at any given time, one and only one of Plus0, Plus1, Plus2, Plus3, Plus4 can be HIGH. However, with extra logic circuitry, the mode select can be encoded as a 3-bit signal instead of 5 separate mode select signals.

While particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that based upon the teachings herein, that changes and modifications may be made without departing from this invention and its broader aspects. Therefore, the appended claims are to encompass within their scope all such changes and modifications as are within the true spirit and scope of this invention. Furthermore, it is to be understood that the invention is solely defined by the appended claims. It will be understood by those with skill in the art that if a specific number of an introduced claim element is intended, such intent will be explicitly recited in the claim, and in the absence of such recitation no such limitation is present. For non-limiting example, as an aid to understanding, the following appended claims contain usage of the introductory phrases “at least one” and “one or more” to introduce claim elements. However, the use of such phrases should not be construed to imply that the introduction of a claim element by the indefinite articles “a” or “an” limits any particular claim containing such introduced claim element to inventions containing only one such element, even when the same claim includes the introductory phrases “one or more” or “at least one” and indefinite articles such as “a” or “an”; the same holds true for the use in the claims of definite articles.

The invention claimed is:

1. An incrementor circuit for computing an output data word by increasing an input data word magnitude by one of a plurality of integers, said incrementor circuit comprising:
  - a mode circuit for receiving an input mode indication designating one of the plurality of integers for increasing the input data word magnitude and providing a mode select signal in response thereto;

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a first multiplex circuit connected to receive the input data word and providing binary values of selected bit positions of the input data word to a constant integer incrementor according to the mode select signal;

the constant integer incrementor increasing the magnitude of received binary values of the selected bit positions of the input data word and connected to provide binary values to a second multiplex circuit; and

the second multiplex circuit including logic to receive the parallel binary values from the constant value incrementor and the input data word and, according to the increment mode signal, provide an output representing the input data word magnitude increased by a selected integer value.

2. The incrementor circuit according to claim 1 wherein constant integer adder adds a single bit value of 1 to the input data word.

3. The incrementor circuit according to claim 1 wherein the plurality of integer values includes at least 3 non-zero integers.

4. The incrementor circuit according to claim 1 wherein the second multiplex circuit includes a logic circuit to combine the mode select signal with one of the input data word bit position values.

5. The incrementor circuit according to claim 1 wherein the constant integer adder is connected to receive a null value at a most significant bit position.

6. The incrementor circuit according to claim 1 wherein the second multiplex circuit includes an input select logic circuit logically combining the mode select signal with input data word bit position values.

7. The incrementor circuit according to claim 1 wherein the second multiplex circuit includes an inverter to receive a least significant bit position value from the input data word to provide an inverted value to an AND gate which is also connected to receive the mode select signal.

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